to room temperature and stirred overnight. A dark blue-green solid was collected and purified by column chromatography on silica gel (hexane–CH_2Cl_2) to give the azo dye: yield 0.5 g (49%); mp 137–140 °C; NMR (^1H, 360 MHz, $CDCl_3$) δ 1.0 (6 H, t), 1.5 (4 H, m), 1.7 (4 H, m), 3.4 (4 H, t), 6.7 (2 H, d), 7.9 (2 H, d), 8.0 (2 H, d), 8.2 (2 H, d); UV–vis (CH_2Cl_2) λ_{max} 417, 625 nm. Anal. Calcd for $C_{25}H_{26}N_6$: C, 73.14; H, 6.38; N, 20.47. Found: C, 72.54; H, 6.40; N, 20.26.

***p*-Nitro-*N*,*N*-dioctadecylaniline.** *p*-Fluoronitrobenzene (15.2 g, 0.11 mol), dioctadecylamine (57.2 g, 0.11 mol), and triethylamine (15.3 mL, 0.11 mol) were dissolved in 20 mL of 1-methyl-2-pyrrolidinone (NMP) and heated at 100 °C overnight with stirring. A yellow solid that precipitated during the heating was collected on a Buchner funnel, triturated, and washed with warm EtOH. A second fraction was isolated by mixing the NMP filtrate with hot EtOH and filtering the resulting solid: yield 45 g (64%); mp 85–88 °C; NMR (^1H, 360 MHz, $CDCl_3$) δ 0.9 (6 H, t), 1.25 (60 H, m), 1.6 (4 H, m), 2.7 (4 H, t), 6.5 (2 H, d), 8.05 (2 H, d).

***p*-Amino-*N*,*N*-dioctadecylaniline.** *p*-Nitro-*N*,*N*-dioctadecylaniline (3 g, 0.0046 mol), $SnCl_2 \cdot 2H_2O$[12] (4.7 g, 0.021 mol), and Sn (0.55 g, 0.0046 mol) were added to a mixture of concentrated HCl (15 mL), toluene (15 mL), and EtOH (45 mL), which was refluxed overnight with stirring. After cooling, petroleum ether (50 mL) was added to the reaction mixture, and this solution was poured into H_2O (100 mL). The aqueous layer was brought to pH 8 with saturated Na_2CO_3 solution. The petroleum ether layer was separated, and the aqueous layer washed with two 50-mL portions of petroleum ether. The combined petroleum ether fractions were dried over anhydrous Na_2CO_3, and the solvent was removed on a rotary evaporator to give a light brown oil used without further purification: yield 2.5 g (89%); NMR (^1H, 360 MHz, $CDCl_3$) δ 0.9 (6 H, t), 1.25 (60 H, m), 1.5 (4 H, m), 3.1 (4 H, t), 6.6 (4 H, AB quartet).

***N*,*N*-Dioctadecylaniline.** *p*-Amino-*N*,*N*-dioctadecylaniline (2.5 g, 0.004 mol) was dissolved in a mixture of H_3PO_2[13] (10 mL) and EtOH (10 mL) with stirring at 0 °C. Sodium nitrite (0.4 g, 0.006 mol) was added in small portions over 5 min while the temperature was maintained below 5 °C. The solution turned red, and the stirring was continued for 30 min at 0 °C and then overnight at room temperature. Aqueous NaOH (5 g in 60 mL of H_2O) was added, and the solution was extracted with two portions (100 mL) of petroleum ether. The organic layer was dried over anhydrous K_2CO_3 and concentrated on a rotary evaporator. The brown oil was chromatographed on 50 g of neutral alumina with petroleum ether as the eluent to give a light tan wax, which was used without further purification: yield 1.5 g (63%); mp 40–41 °C; NMR (^1H, 360 MHz, $CDCl_3$) δ 0.9 (6 H, t), 1.3 (60 H, m), 1.55 (4 H, m), 3.2 (4 H, t), 6.6 (3 H, m), 7.2 (2 H, m); MS, *m/e* (relative intensity) 598 (4, M^+), 358 (56), 120 (100), 43 (66). Anal. Calcd for $C_{42}H_{79}N$: C, 84.34; H, 13.31; N, 2.34. Found: C, 84.04; H, 13.34; N, 2.39.

[[4-[[4-(Dioctadecylamino)phenyl]azo]phenyl]methylene]propanedinitrile. Dioctadecylaniline (0.37 g, 0.6 mmol) was dissolved in 30 mL of glacial AcOH at room temperature. (Dicyanovinyl)benzenediazonium hexafluorophosphate (0.25 g (80% diazonium salt), 0.6 mmol) was added with vigorous stirring. After 15 min, NaOAc (0.098 g, 1.2 mmol) was added in two portions, and the solution was then stirred overnight. A dark red solid was collected and purified by column chromatography on silica gel (20 g) with hexane–EtOAc to give the desired product: yield 0.4 g, (85%); mp 59–60 °C; NMR (^1H, 360 MHz, $CDCl_3$) δ 0.85 (6 H, t), 1.25 (60 H, m), 1.6 (4 H, m), 3.35 (4 H, t), 6.67 (2 H, d), 7.75 (1 H, s), 7.86 (2 H, d), 7.90 (2 H, d), 8.0 (2 H, d). Anal. Calcd for $C_{52}H_{83}N_5$: C, 80.25; H, 10.75; N, 9.00. Found: C, 79.65; H, 10.68; N, 8.54.

[4-[[4-(Dioctadecylamino)phenyl]azo]phenyl]ethenetricarbonitrile. Via a similar procedure to that described above, dioctadecylaniline was reacted with (tricyanovinyl)benzenediazonium hexafluorophosphate in glacial acetic acid/solution acetate. After being stirred overnight, the AcOH solution was poured into H_2O and stirred for 10 min. The blue-black solid was collected on a Buchner funnel and purified by column chromatography on silica gel with hexane/EtOAc: yield 0.51 g (80%); mp 35–37 °C; NMR (^1H, 360 MHz, $CDCl_3$) δ 0.85 (6 H, t), 1.25 (60 H, m), 1.6 (4 H, m), 3.35 (4 H, t), 6.7 (2 H, d), 7.85 (2 H, d), 7.95 (2 H, d), 8.1 (2 H, d). Anal. Calcd for $C_{53}H_{82}N_6$: C, 79.25; H, 10.29; N, 10.46. Found: C, 79.31; H, 10.18; N, 10.02.

Coupling of *p*-(Dicyanovinyl)benzenediazonium Hexafluorophosphate to Copolymers of (*N*-Ethylanilino)ethyl Methacrylate and Methyl Methacrylate. The copolymer was dissolved in AcOH (20 mL/g) and stirred overnight with 1.25 equiv of the diazonium salt and 2 equiv of NaOAc. The solids were allowed to settle, and the supernatant liquid was decanted into 5 volumes of stirred water. The residual solids were dissolved in MEK with stirring and added to the aqueous mixture. The precipitated solids were collected and dried in air. An impurity absorbing at 440 nm was removed by reprecipitation from MEK–CCl_4, and an ionic impurity was removed by reprecipitation from MEK–dilute aqueous NaOAc. The yield was 60–90%: NMR ($CDCl_3$, back-bone omitted) δ 3.6 (OCH_3 and NCH_2), 4.1 (OCH_2), 6.8 and 7.9 (Ar H and vinyl H); UV max (film) 510, (Me_2SO) 510 nm. Coupling with *p*-(tricyanovinyl)benzenediazonium hexafluorophosphate was accomplished in a similar manner, and its absorption maximum was at 580 nm (film).

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Registry No. 4-(Dicyanovinyl)aniline, 17082-32-5; [[4-[[4-(dibutylamino)phenyl]azo]phenyl]methylene]propanedinitrile, 116350-27-7; dibutylaniline, 613-29-6; *p*-nitro-*N*,*N*-dioctadecylaniline, 116350-26-6; *p*-fluoronitrobenzene, 350-46-9; dioctadecylamine, 112-99-2; *p*-amino-*N*,*N*-dioctadecylaniline, 85074-67-5; [[4-[[4-(dioctadecylamino)phenyl]azo]phenyl]methylene]propanedinitrile, 116350-28-8; dioctadecylaniline, 72072-19-6; [4-[[4-(dioctadecylamino)phenyl]azo]phenyl]ethenetricarbonitrile, 116350-29-9.

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Lewis Acid Induced α-Alkoxyalkylation of 1,3-Dicarbonyl Compounds

R. Antonioletti, F. Bonadies, and A. Scettri*

Centro di Studio per la Chimica delle Sostanze Organiche Naturali del CNR, Dipartimento di Chimica, Università "La Sapienza", P. le delle Scienze 5, I-00185 Roma, Italy

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The α-alkoxyalkylation of carbonyl compounds represents one of the most important C–C bond forming reactions.[1] In the last few years an impressive series of papers appeared in the literature, showing that Lewis acid induced α-hydroxy- and α-alkoxyalkylation of carbonyl compounds could be achieved via the corresponding enol esters, alkyl enol ethers, or, more conveniently, silyl enol ethers.[2] Furthermore, high enantioselectivity or stereoselectivity is possible by using suitable Lewis acids.[3,4] In particular, the employment of trimethylsilyl trifluoromethanesulfonate (TMSOTf), an efficient catalyst in the aldol-type condensation of enol silyl ethers with acetals or ketals, has allowed the formation of adducts with a high to moderate degree of stereoselectivity.[3]

On the other hand, successful α-alkoxyalkylations of active methylene compounds of type 1[5] are often precluded

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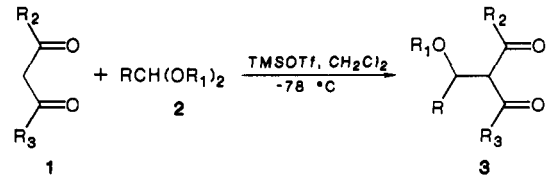
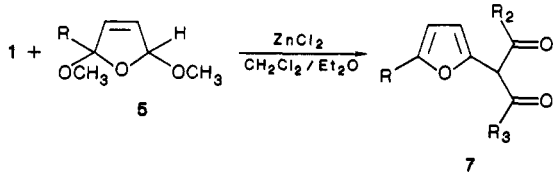
Table I. TMSOTf-Induced α-Alkoxyalkylation of 1



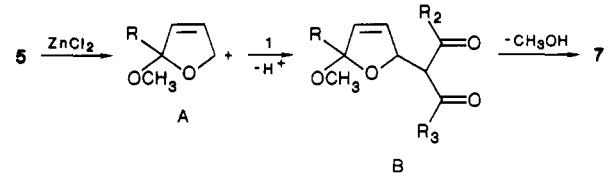
entry	2 R	2 R_1	1 R_2	1 R_3	product	% yield[a]
a	Ph	Me	Ph	Ph	**3a**	88
b	Ph	Me	Ph	OEt	**3b**	93[b]
c	Ph	Me	Ph	Me	**3c**	95[b]
d	Ph	Me	Me	OEt	**3d**	97[b]
e	Me	Et	Ph	Ph	**3e**	91
f	Et	Et	Ph	Ph	**3f**	89
g	CH_2Br	Et	Ph	Ph	**3g**	86
h	CH_2Br	Et	Ph	OEt	**3h**	90[b]

[a] Isolated yields. [b] Mixture of diastereoisomers.

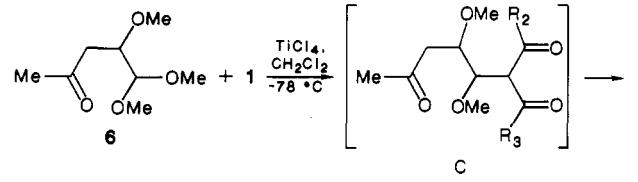
Scheme I



Scheme II



Scheme III



because of their preferential reactivity toward many Lewis acids that lead to unreactive coordination complexes under the above conditions[6] or to O-metalation products.[7]

In this paper we report that 1,3-dicarbonyl compounds 1 undergo direct and efficient α-alkoxyalkylation, promoted by Lewis acids, suitably chosen according to the reactivity of the acetals employed as starting materials. In fact, treatment of 1 with acetals 2, in dichloromethane solution at −78 °C in the presence of TMSOTf (procedure A), affords the condensation products 3 in very good yields (Table I).

The adducts 3, contaminated by small amounts of the starting materials 1 (1–3%), are exclusively isolated in most cases; none of the reactions gave rise to di- or polycondensation products or α,β-unsaturated carbonyl compounds, which are formed in the usual base-promoted aldol condensation. Similar results were obtained with α-bromo acetals, although the products (**3f** and **3g**) had pronounced tendency to undergo a furan ring closure. In the reactions creating new chiral centers, a poor degree of stereoselectivity was obtained and, furthermore, the composition of the diastereoisomeric mixtures varied considerably, probably because of the easy enolization of 1,3-dicarbonyl moiety of 3.

Furthermore, the above approach seemed to be affected by steric limitations, as supported by the complete failure of attempted α-alkoxyalkylation both of 1 with ketals and of 2-alkyl-substituted 1,3-dicarbonyl compounds with acetals. However, in the former case, e.g., treatment of benzoylacetone with 2,2-dimethoxypropane for 24 h under the usual conditions, the active methylene compound was recovered (65%) and, rather surprisingly, the corresponding alkyl enol ether, 1-phenyl-3-methoxybut-2-en-1-one, was isolated in poor yield (25%).

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Table II. $ZnCl_2$- and $TiCl_4$-Induced Formation of Furans 7

entry	acetal	1,3-dicarbonyl compound	product	% yield[a]
a	5, R = H	R_2 = Me; R_3 = OEt	**7a**	63
b	5, R = H	R_2 = Me; R_3 = Me	**7b**	77
c	5, R = H	R_2 = *n*-pent; R_3 = OEt	**7c**	64
d	5, R = Me	R_2 = Me; R_3 = OEt	**7d**	65
e	6	R_2 = Me; R_3 = Me	**7e**	70
f	6	R_2 = Ph; R_3 = OEt	**7f**	55
g	6	R_2 = Me; R_3 = OEt	**7d**	60
h	6	R_2 = Ph; R_3 = Me	**7g**	62
i	6	R_2 = Ph; R_3 = Ph	**7h**	60

[a] The yields refer to isolated, chromatographically pure compounds 7.

The employment, as starting material, of cyclic unsaturated acetals of type 5 required milder conditions, since they underwent very fast decomposition in the presence of TMSOTf. However, the reaction, promoted by zinc chloride, proceeded rather satisfactorily in 1/1 dichloromethane/diethyl ether solution at room temperature (procedure B), affording directly the furan derivatives 7 (Scheme I).

This result could be reasonably explained by assuming the previous formation of the intermediate cation A by action of the Lewis acid, which reacted with the active methylene compound 1 to give the adduct **B**; formation of the final product 7 then occurred through elimination of methanol (Scheme II).

The approach proved to be successful even in the case of acetals containing additional groups, such as 4,5,5-trimethoxypentan-2-one (6) (Scheme III).

In fact, we found that under the typical Mukaiyama reaction conditions, $TiCl_4$ in dichloromethane solution at −78 °C (procedure C),[8] the condensation of 1 with 6 occurred, leading again to the furan derivatives 7 in appreciable yields (Table II). The conversion presumably involved the fast formation of intermediate adduct C by chemoselective attack on the acetal function and then slower cyclization to furan 7.

Besides the satisfactory degree of applicability of the above approach, it has to be noted that the formation of the same furan **7d** through both procedure B and C (entries d and g, Table II) disclosed a previously unknown synthetic equivalence between 2-methyl-2,5-dihydro-2,5-dimethoxyfuran (**5**) (R = Me) and 4,5,5-trimethoxypentan-2-one.

Experimental Section

Ethyl 2-(Methoxyphenylmethyl)-3-oxobutanoate (3d): Procedure A. To a stirred solution of ethyl 3-oxobutanoate (5.0 mmol) and benzaldehyde dimethyl acetal (8.0 mmol) in dry dichloromethane (40 mL) was added dropwise a solution of trimethylsilyl trifluoromethanesulfonate (8.0 mmol) in dry dichloromethane (10 mL) under a nitrogen atmosphere at −78 °C (−25 °C for entries g and h, Table I) over a period of 5 min. The reaction was monitored by TLC and continued until the disappearance of the 1,3-dicarbonyl compound. Then, diethyl ether (200 mL) was added, and the solution was washed with cold water (3 × 15 mL) and dried over anhydrous sodium sulfate. After the removal of the solvent in vacuo, the resulting crude product was purified by column chromatography on silica gel. Elution with 9/1 *n*-pentane/diethyl ether afforded **3d** (97% yield) as an unseparable mixture of 1/1 erythro and threo stereoisomers. ^1H NMR (CCl_4): δ 7.30 (s, 5 H), 4.80 and 4.77 (2 d, 1 H, J = 10 Hz), 3.7–4.2 (m, 3 H), 3.20, 3.14, and 3.10 (3 s, 3 H), 2.35 and 1.90 (2 s, 3 H), 1.30, 1.28, and 1.00 (3 t, 3 H, J = 7 Hz). IR (1% CCl_4, ν_{max}, cm^{-1}): 3097, 3076, 3040, 1760, 1725, 1622, 1458, 1110, 702. MS, m/z 250 (M^+). Anal. Calcd for $C_{14}H_{18}O_4$: C, 67.18; H, 7.25. Found: C, 67.09; H, 7.30.

Ethyl 2-(5-Methyl-2-furyl)-3-oxobutanoate (7d): Procedure B. To a stirred solution of ethyl 3-oxobutanoate (6.0 mmol) and 2-methyl-2,5-dihydro-2,5-dimethoxyfuran[9] (**5**, R = Me) (6.0 mmol) in a 1/1 (v/v) mixture of dry CH_2Cl_2/Et_2O (50 mL) was added $ZnCl_2$ (6.0 mmol) under a nitrogen atmosphere at room temperature over a period of 30 min. After 48 h, diethyl ether (200 mL) was added, and the resulting solution was submitted to the same workup as in procedure A. Pure **7d** (65% yield) was isolated as rather dense oil (n^{19} 1.4905) through silica gel chromatography by elution with 9/1 *n*-pentane/Et_2O. ^1H NMR (CCl_4): δ 13.23 (s, 1 H), 5.91 (d, 1 H, J = 3 Hz), 5.71 (d, 1 H, J = 3 Hz), 4.15 (q, 2 H, J = 7 Hz), 2.25 (s, 3 H), 1.94 (s, 3 H), 1.23 (t, 3 H, J = 7 Hz). IR (1% CCl_4, ν_{max}, cm^{-1}): 1730, 1710 (br), 1650, 1600, 1270, 1230. MS: m/z 210 (M^+). Anal. Calcd for $C_{11}H_{14}O_4$: C, 62.85; H, 6.71. Found: C, 62.98; H, 6.77.

Ethyl 2-(5-Methyl-2-furyl)-3-oxobutanoate (7d): Procedure C. To a stirred solution of ethyl 3-oxobutanoate (6.0 mmol) and 4,5,5-trimethoxypentan-2-one (**6**) (6.6 mmol), prepared according the procedure reported in ref 10, in dry dichloromethane (40 mL) was added dropwise a solution of titanium tetrachloride (6.6 mmol) in dry dichloromethane (10 mL) under a nitrogen atmosphere at −78 °C over a period of 5 min. After the disappearance of 1,3-dicarbonyl compound (2 h), the mixture was stirred at room temperature for 24 h to complete the furanization process. Then, diethyl ether (200 mL) was added, and the resulting solution was submitted to the same workup as in procedure A, and chromatographic purification afforded pure **7d** (60% yield).

Supplementary Material Available: Analytical and spectral data for adducts 3 and furans 7 (2 pages). Ordering information is given on any current masthead page.

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Preparation of (+)- and (−)-*N*,*S*-Dimethyl-*S*-phenylsulfoximine via an Improved Resolution. Accurate Determination of Very High Enantiomeric Purities by On-Column GC Analysis of Diastereomeric Derivatives

Christopher S. Shiner* and Andrew H. Berks

Department of Chemistry and Biochemistry, University of Colorado, Boulder, Colorado 80309-0215

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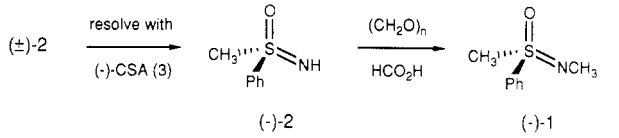
(+)- and (−)-*N*,*S*-Dimethyl-*S*-phenylsulfoximine (**1**) have been employed in asymmetric syntheses, resolutions, and mechanistic studies.[1,2] The nonracemic sulfoximines are readily available via resolution of *S*-methyl-*S*-phenylsulfoximine (**2**) with (+)- or (−)-10-camphorsulfonic acid (**3**), followed by N-methylation.[3-5] However, the reported



procedure apparently has often furnished material of only 90–99% ee.[6] We recently employed the sulfoximine method for resolution of camphenilone (**4**),[7,8] and after considerable experimentation the published resolution afforded **1** of 98–99% ee. Herein we report that recrystallization of the camphorsulfonate salts **5** and *ent*-**5** furnished both antipodes of **2** and ultimately of **1** in greater than 99.9% enantiomeric purity. On-column capillary GC analysis of the camphanyl derivative of **2** comprised an accurate and convenient method for ee determination. An improved procedure facilitated the N-methylation of **2**, and the use of silver nitrate impregnated silica gel for chromatography further enhanced the camphenilone resolution.

The enantiomeric purities of sulfoximines **1** and **2** have previously been evaluated via polarimetry, an inherently imprecise and unreliable technique.[9] Racemic **2** and **1** have also been resolved by analytical HPLC on a chiral stationary phase.[10] We determined the ee of **2** or the de of derived camphorsulfonate salts (e.g., **5**) via N-acylation with commercially available (−)-camphanic acid chloride

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(4) The chemistry of sulfoximine-mediated ketone resolution can be employed in conjunction with homochiral ketones for resolution of 1 (ref 1b).
(5) Sulfoximines have also been resolved via chromatography on chiral stationary phases: Allenmark, S.; Nielsen, L.; Pirkle, W. H. *Acta Chem. Scand., Ser. B* **1983**, *B37*, 325–328. See also ref 10.
(6) See, for example: (a) Reference 2. (b) Zimmerman, H. E.; Solomon, R. D. *J. Am. Chem. Soc.* **1986**, *108*, 6276–6289.
(7) Shiner, C. S.; Berks, A. H.; Fisher, A. M. *J. Am. Chem. Soc.* **1988**, *110*, 957–958.
(8) Resolution of camphenilone via the sulfoximine method has been described previously (ref 2b).
(9) For discussion see, for example: Rosen, T.; Watanabe, M.; Heathcock, C. H. *J. Org. Chem.* **1984**, *49*, 3657–3659. Review of polarimetry: Lyle, G. G.; Lyle, R. E. In *Asymmetric Synthesis*; Morrison, J. D., Ed.; Academic: New York, 1983; Vol. 1, Chapter 2.
(10) Wainer, I. W.; Alembik, M. C.; Johnson, C. R. *J. Chromatogr.* **1986**, *361*, 374–378. The accuracy of this method for determination of high enantiomeric purities was not investigated. Although this approach obviates the derivatization of **2**, the sulfoximine must be isolated from the camphorsulfonate salt prior to the analysis, and a special HPLC column is required.

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